***Systems-Thinking**: Study of a system to find the nature of interdependencies. What happens when one element of a system changes? How do the parts influence each other? The distinction between a "system" and a "heap" is the interdependent links between elements. If you take an element out of a heap, it doesn't have an impact. If you take an element out of a system, it impacts at least one other element of the system.*

How will Systems-Thinking skills help our students?

Since our first Earth Day 33 years ago, teachers have sought ways to nurture civic engagement skills regarding environmental issues. Our future depends on the next generation's ability to make informed decisions and engage in "Earth Citizen" policy-making efforts for a sustainable future, both for themselves and for their children. District-by-district efforts towards greening buildings, increasing recycling, reducing waste, and teaching environmental literacy are all incredible accomplishments, given teachers' time and resources for these endeavors.

However, to optimize outcomes from these environmentally-minded commitments, students need sophisticated skills to identify the complex systems we all engage in, and identify how a change to one element of a system impacts the remaining elements. This way of expanding our thinking is called **Systems Thinking**. At an elementary grade level, exercising this skill can be easily incorporated into ELA reading and writing. As a science tool, it supports Science standards for scientific reasoning.

The field of Systems-Thinking Modeling is most often associated with organizational transformation, and as an analytical business tool that requires extremely complex modeling and representational skills. This CELF handout is simply an introductory guide to the potential application and benefit of systems thinking skills for our next generation of decision makers. Although an educational pedagogy for Systems Thinking Modeling is still being developed, it is increasingly viewed as a way to realize the full educational benefit of environmental literacy by putting that content in the context of changing systems, while also engaging students in the 12 **Big Ideas of Education for Sustainability.**[i] In order to create and live in a sustainable future, students benefit from a meaningful understanding of the following Big Ideas of Education for Sustainability concepts: *Community, Systems, Diversity, Interdependence, Cycles, Change Over Time, Limits, Long-Term Effects* and *Equilibrium*. Student understanding and application of *Fairness/Equity, Place,* and *Ability to Make a Difference* are demonstrated as a result of experience with systems-thinking.

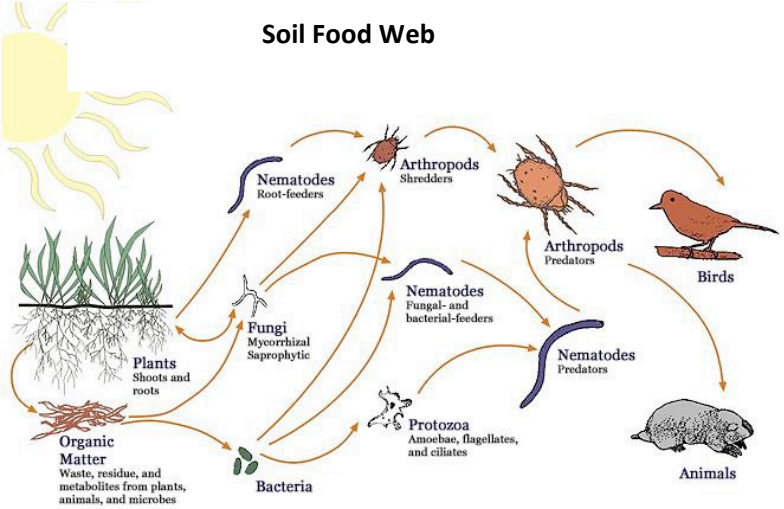
As a resource for ELA connections to Systems-Thinking, we recommend When a Butterfly Sneezes, by Linda Booth Sweeney, who created several system- thinking professional development tools for both educators and corporate leaders. Linda realized that elementary ELA standards offer a rich opportunity for foundational exposure to systems thinking. The title of her book refers to "the butterfly effect" – how a small change to an initial condition can affect large complex systems.[ii]

Tendency towards Linear story-telling: In the primary grades, supporting student story retelling and sequencing skills reinforce the use of "first, then, next, finally" and steers students towards linear storytelling and comprehension. L.B. Sweeney recognized that many children's picture books that appear linear on one level, can provide practice, not only in identifying a system, but in examining impacts within the system.

The Web of Life Activity: An ideal introduction for students to see interconnections and understand unanticipated consequences is through the **Web of Life** activity. Students discover interdependencies of system elements. You can find instructions for this 15 minute activity here: http://forces.si.edu/main/pdf/PreK-1-WebofLife.pdf. This activity can be used in alignment with NYC Scope and Sequence and CCLS ELA standards (see next page).A Youtube video demonstrating the game is found here: http://www.youtube.com/watch?v=Fivc08jK2OE.

Experience identifying a System: There are many gateways for students to gain experience identifying systems. A family, school and community are all **systems** rather than **heaps**. A heap is a set of elements that are unchanged when one element is removed. (E.g., taking a pair of shoes out of your shoe closet doesn't change the remaining shoes.) Reviewing just one web of life in a natural system will give students a visual template to create models of other systems. From p.151 of Dr. Art's Guide to Science: *"All the different ecosystems have a similar pattern of organization. They all require a source of energy and a group of organisms that can capture that energy and store it in chemical form. For the vas t majority of ecosystems, the sun provides the energy. Plant life, ranging from microscopic algae to towering redwood trees, captures the energy in sunlight and stores it as chemical energy in sugar molecules."* Ecosystem Organisms: Producers, Herbivores, Carnivores and Decomposers.

Soil Food Web

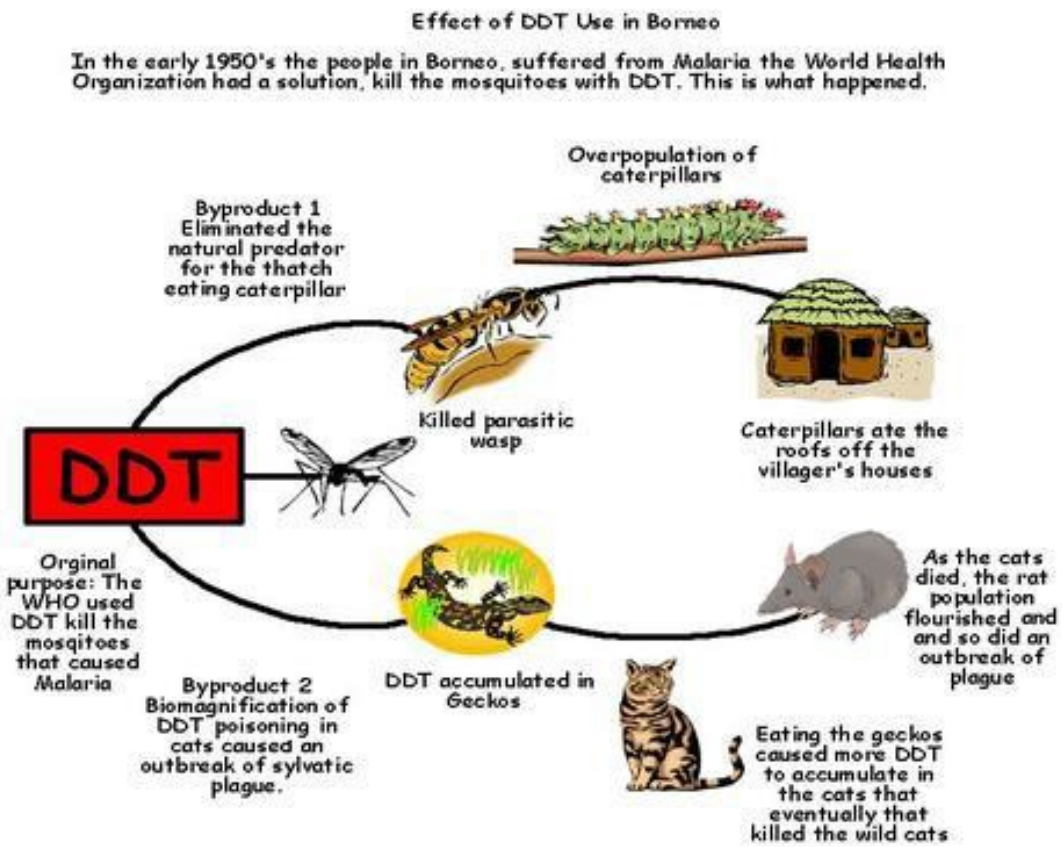


http://lifeunderyourfeet.org/en/soileco/intro/biogeochemistry.asp

Photo of pyramids from Dr. Art's Guide to Science, p.237. (Note the size of the producer in this pyramid, and what happens when the producer is impacted.)

Systems Modeling: Creating Food Webs and pyramids are one type of model that shows relationships between parts. **Systems Modeling** goes beyond identifying relationships – systems modeling shows the impact and behavior-- **WHAT HAPPENS** --between elements within a system.

WHO (World Health Organization) had not done Systems Modeling: The Day They Parachuted Cats on Borneo



The Language of Systems-Thinking[iii]

Studying food webs and food chains within identified ecosystems helps students learn the elements of a system, but what happens to the food web when one or more elements is changed? Students can answer this question by using the language of systems thinking, creating a Causal Loop Diagram (CLD), "lowering the water line, and seeing the whole iceberg rather than just the tip."

FEEDBACK LOOPS DESCRIBE TWO WAYS IN WHICH SYSTEM COMPONENTS WORK.

Balancing Feedback Loops: (Hawks/mice) elements tend to stay in balance throughout the loop. System resets itself to balance.

Reinforcing Feedback Loops: a change in one direction continues the change in that direction. (E.g., introducing rabbits into a system without predators leads to a rabbit population explosion.)

Stock: An accumulation of material or information that has built up in a system over time.

Flow: Material or information that enters or leaves a stock over a period of time.

SYSTEMS ARCHETYPES

Fixes that Fail: quick and easy solutions often make a situation worse

Limits to Success: time horizons and delays result in actuated limits (e.g., a flooded market)

Tragedy of the Commons: cumulative effect of individual actions (e.g., pollution, littering)

Shifting the Burden: taking action to treat the symptom without solving the initial problem (e.g., borrowing more money to cover overspending)

Escalation: reinforcing loop based on two elements' mutually increasing actions.

Causal Loop Diagram Symbols

R	Reinforcing feedback loop
B	Balancing feedback loop
+ → S	Causal link where X adds to Y or X causes a change in Y in the same direction.
− → O	Causal link between two variables where X subtracts from Y or X causes a change in Y in the opposite direction.

Systems-Thinking Standards Alignment

Grade Level	NYC DoE Scope and Sequence	**CCLS ELA** Integration of Knowledge and Ideas, Research to Build and Present Knowledge, Speaking and Listening Standards	**EfS Standards** (met through all Systems-Thinking work)
K	**SC** Unit 1 Trees Through the Seasons **SS** Unit 1 School, Unit 3 Families, Unit 4 Neighborhood	**Literacy RI.K.7** -Students can draw relationships within a system or "Web of Life" and describe an element that is interdependent within that web. The web or system can be a family or community group. **Literacy W.K.7** – With guidance and support from adults, recall information from experiences and gather information from sources to answer a question.	**Sustainable Schools Project EfS Big Ideas of Sustainability**: Community, Systems, Diversity, Interdependence Cycles, Change over time Limits, Fairness/Equity, Place Ability to Make a Difference, Long-term Effects, Equilibrium **US Partnership for Education for Sustainable Development (USPESD) EfS Standard 2**: Students recognize the concept of sustainability as a dynamic condition characterized by the interdependency among ecological, economic and social systems and how these interconnected systems affect individual and societal well-being. They develop an understanding of the human connection to and interdependence with the natural world.
1	**SC** Unit 1 Animal Diversity; **SC** Unit 3 Weather and Seasons; **SS** Unit 2 Families, Now and Long Ago	**Literacy W2.3** Write narratives in which experience and story of system or web is represented as a complex set of relationships. **Literacy SL.1.1** Participate in collaborative conversations with diverse partners about grade 1 topics… **Literacy SL.1.1b** Build on others' talk in conversations by responding to the comments of others through multiple exchanges.	
2	**SC** Unit 3 Plant Diversity; **SS** Unit 3 Urban, Suburban and Rural Communities	**Literacy SL.2.1** Participate in collaborative conversations with diverse partners about grade 2 topics… **Literacy SL.2.2** Recount or describe key ideas or details from a text read aloud or information presented orally or through other media.	
3	**SC** Unit 4 Plant and Animal Adaptations **SS** Unit 1 Intro to World Communities	**Literacy W.3.8** Recall information from experiences…take brief notes on sources and sort evidence into provided categories. **Literacy SL.3.1** Engage effectively in a range of collaborative discussions with diverse partners on grade 3 topics…	
4	**SC** Unit 1 Animals and Plants in their Environ. **SS** Unit 2 Three Worlds Meet	**Literacy RI.4.7** Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, timelines…) and explain how the information contributes to an understanding of the text in which it appears.	
5	**SC** Unit 4 Exploring Ecosystems; **SS** Unit 1 – Geography influence develop. of W. Hemisph.	**Literacy SL.5.1** Engage in a range of collaborative discussions. **Literacy SL 5.5** Include multimedia components and visual displays in presentations when appropriate to enhance the development of main ideas or themes.	

RESOURCES

Creative Learning Exchange. http://www.clexchange.org/. This website is devoted to teacher and student access to resources supporting systems-thinking modeling applications in K-12 learning settings.

Pomerantz, Charlotte. The Day they Parachuted Cats On Borneo. MA: Young Scott Books, 1971. Book.

Shelburne Farms' Sustainable Schools Project. The Guide to Education for Sustainability. The Big Ideas of Sustainability. 2011. P.3.

Sussman, Art. CA: Dr. Art's Guide to Science: Connecting atoms, galaxies, and everything in between. Jossey-Bass, 2006. Book.

Sweeney, Linda Booth. When a Butterfly Sneezes. MA: Pegasus Communications, 2001. Book.

United States Partnership for Education for Sustainable Development. National Education for Sustainability K-12 Student Learning Standards. Version 3 – September 2009. Endorsed by National Council for the Social Studies. http://www.ncss.org

Since When a Butterfly Sneezes is currently out of print, we wanted to be sure you have a list of the children's literature used in that systems-thinking guide, as well as access to lesson plans to utilize that approach:

When a Butterfly Sneezes uses these children's books to explore systems-thinking archetypes:		
If You Give a Mouse a Cookie The Old Ladies Who Liked Cats The Cat in the Hat Comes Back Once a Mouse: A Fable Cut in Wood The Sneetches and Other Stories Anno's Magic Seeds	Zoom A River Ran Wild The Butter Battle Book Tree of Life: The World of the African Baobab The Lorax Who Speaks for Wolf: A Native American Learning Story	Facing the Future. (2007) Teaching Global Sustainability in the Primary Grades: a K-4 Curriculum Guide. Lesson Planner 4: Problems and Fixes. P.50-64. http://www.facingthefuture.org

[i] From page 3 of the Guide to Education for Sustainability, produced by Shelburne Farms' Sustainable Schools Project in 2011. http://sustainableschoolsproject.org/tools-resources.

[ii] According to the Merriam-Webster dictionary, the "butterfly effect" is a property of chaotic systems by which small changes in initial conditions can lead to large-scale and unpredictable variation in the future state of the system.

[iii] This is not a complete list of terms, archetypes or diagrams used in Systems-Thinking and modeling. Consider this partial list an introduction. For more information, see the resources listed in this packet.